

EXHIBIT I



US008746330B2

(12) **United States Patent**
Lyon

(10) **Patent No.:** US 8,746,330 B2
(45) **Date of Patent:** Jun. 10, 2014

(54) **FLUID HEAT EXCHANGER CONFIGURED TO PROVIDE A SPLIT FLOW**(75) Inventor: **Geoff Sean Lyon**, Calgary (CA)(73) Assignee: **Coolit Systems Inc.**, Calgary (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1345 days.

(21) Appl. No.: **12/189,476**(22) Filed: **Aug. 11, 2008**(65) **Prior Publication Data**

US 2009/0071625 A1 Mar. 19, 2009

Related U.S. Application Data

(60) Provisional application No. 60/954,987, filed on Aug. 9, 2007.

(51) **Int. Cl.***F28F 3/14* (2006.01)*F28F 3/12* (2006.01)*F28F 7/00* (2006.01)*H05K 7/20* (2006.01)(52) **U.S. Cl.**USPC **165/170; 165/168; 165/80.4; 361/699**(58) **Field of Classification Search**USPC **165/168, 170, 80.4; 361/699**

See application file for complete search history.

(56) **References Cited****U.S. PATENT DOCUMENTS**

4,561,040 A * 12/1985 Eastman et al. 361/699

4,750,086 A 6/1988 Mittal

4,898,153 A * 2/1990 Sherwood 126/665

4,909,315 A * 3/1990 Nelson et al. 165/80.3

4,940,085 A * 7/1990 Nelson et al. 165/80.3

5,265,670 A *	11/1993	Zingher	165/80.4
5,294,830 A	3/1994	Young et al.	
5,309,319 A	5/1994	Messina	
5,441,102 A	8/1995	Burward-Hoy	
5,727,618 A *	3/1998	Mundinger et al.	165/80.4
5,823,249 A	10/1998	Batchelder	
6,019,165 A	2/2000	Batchelder	
6,415,860 B1	7/2002	Kelly et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

JP 61032449	2/1986
JP 2002151638	5/2002

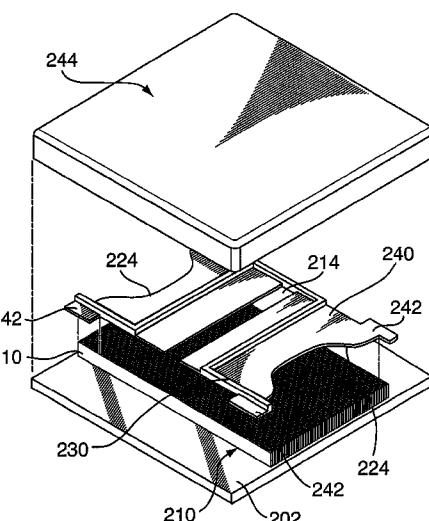
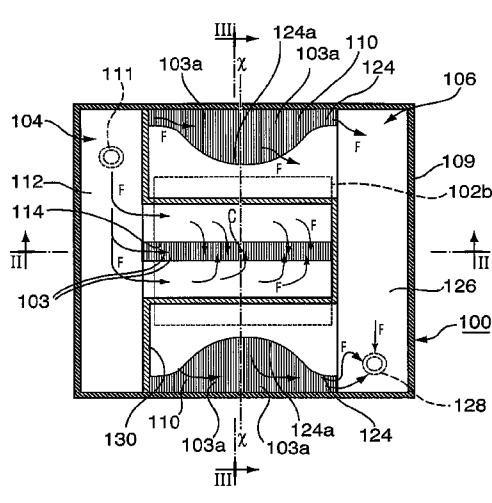
(Continued)

OTHER PUBLICATIONS

Technical Opinion dated Jan. 10, 2013, for Japanese Registration No. 3179086 (Utility Model Application No. 2012-002117); English translation included; 7 pages.

Primary Examiner — Brandon M Rosati(74) *Attorney, Agent, or Firm* — Ganz Law, PC(57) **ABSTRACT**

A fluid heat exchanger can define a plurality of microchannels, each having a first end and an opposite end and extending substantially parallel with each other microchannel. Each microchannel can define a continuous channel flow path between its respective first end and opposite end. A fluid inlet opening for the plurality of microchannels can be positioned between the microchannel first and opposite ends, a first fluid outlet opening from the plurality of microchannels can be positioned adjacent each of the microchannel first ends, and an opposite fluid outlet opening from the plurality of microchannels can be positioned adjacent each of the microchannel opposite ends such that a flow of heat transfer fluid passing into the plurality of microchannels flows along the full length of each of the plurality of microchannels outwardly from the fluid inlet opening. Related methods are disclosed.

28 Claims, 2 Drawing Sheets

US 8,746,330 B2

Page 2

(56)	References Cited					
U.S. PATENT DOCUMENTS						
6,447,270 B1	9/2002	Schmidt et al.	8,240,362	B2	8/2012	Eriksen
6,679,315 B2	1/2004	Cosley et al.	8,245,764	B2	8/2012	Eriksen
6,702,002 B2	3/2004	Wang	2002/0070007	A1 *	6/2002	Calaman et al. 165/80.4
6,952,345 B2	10/2005	Weber et al.	2003/0019234	A1 *	1/2003	Wayburn et al. 62/259.2
6,986,382 B2	1/2006	Upadhyay et al.	2004/0042171	A1	3/2004	Takamatsu et al.
6,988,534 B2	1/2006	Kenny et al.	2004/0042172	A1	3/2004	Kusaka et al.
7,000,684 B2	2/2006	Kenny et al.	2004/0104010	A1	6/2004	Kenny et al.
7,007,506 B2 *	3/2006	Kubo et al. 62/515	2004/0104012	A1	6/2004	Zhou et al.
7,021,367 B2	4/2006	Oikawa	2004/0104022	A1	6/2004	Kenny et al.
7,104,312 B2	9/2006	Goodson et al.	2004/0112585	A1	6/2004	Goodson et al.
7,124,811 B2	10/2006	Crocker et al.	2004/0123614	A1	7/2004	Stewart
7,131,486 B2	11/2006	Goodson et al.	2004/0182548	A1	9/2004	Lovette et al.
7,156,159 B2	1/2007	Lovette et al.	2004/0206477	A1	10/2004	Kenny et al.
7,209,355 B2	4/2007	Koga et al.	2005/0269061	A1	12/2005	Brewer et al.
7,264,359 B2	9/2007	Kawahara et al.	2006/0225867	A1 *	10/2006	Park et al. 165/80.4
7,274,566 B2	9/2007	Campbell et al.	2007/0039719	A1	2/2007	Eriksen et al.
7,301,771 B2	11/2007	Hata et al.	2007/0163750	A1 *	7/2007	Bhatti et al. 165/80.4
7,360,582 B2 *	4/2008	Olesen 165/80.4	JP		2007180505	7/2007
7,466,553 B2	12/2008	Hamman	JP		2007227902	9/2007
7,527,085 B2	5/2009	Iijima et al.	JP		2007531991	11/2007
7,762,314 B2 *	7/2010	Campbell et al. 165/80.3	WO		0165900 A1	9/2001
7,971,632 B2	7/2011	Eriksen et al.				
8,066,057 B2	11/2011	Olesen et al.				

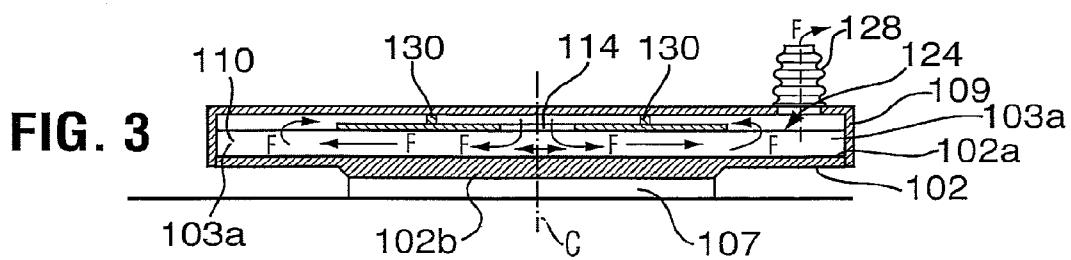
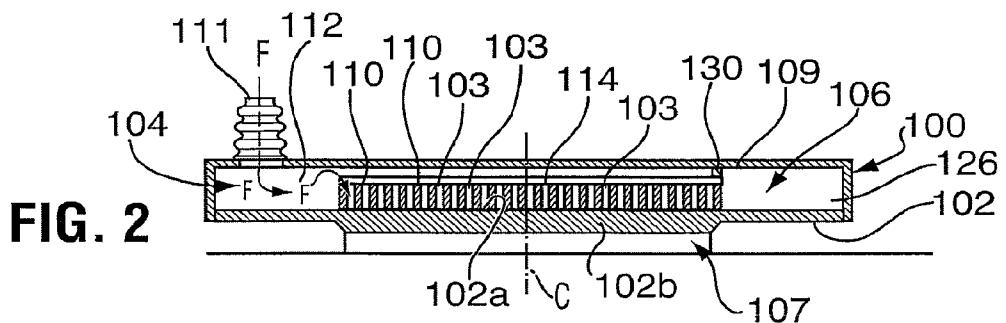
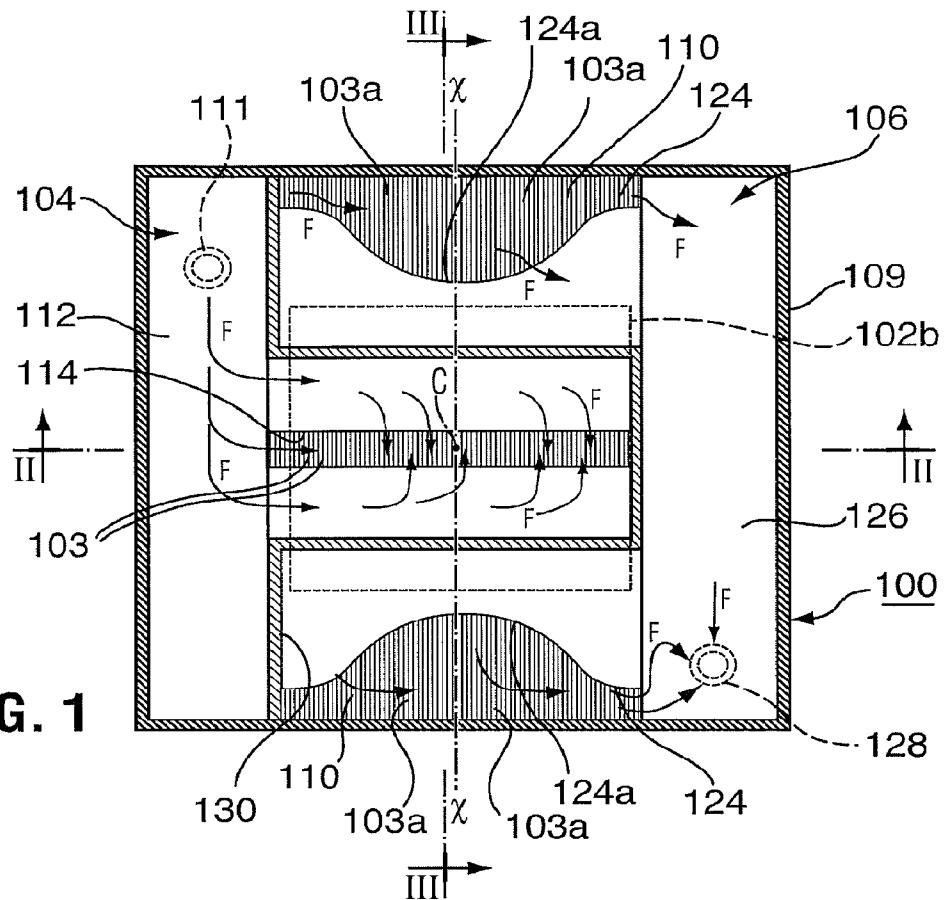
* cited by examiner

U.S. Patent

Jun. 10, 2014

Sheet 1 of 2

US 8,746,330 B2



U.S. Patent

Jun. 10, 2014

Sheet 2 of 2

US 8,746,330 B2

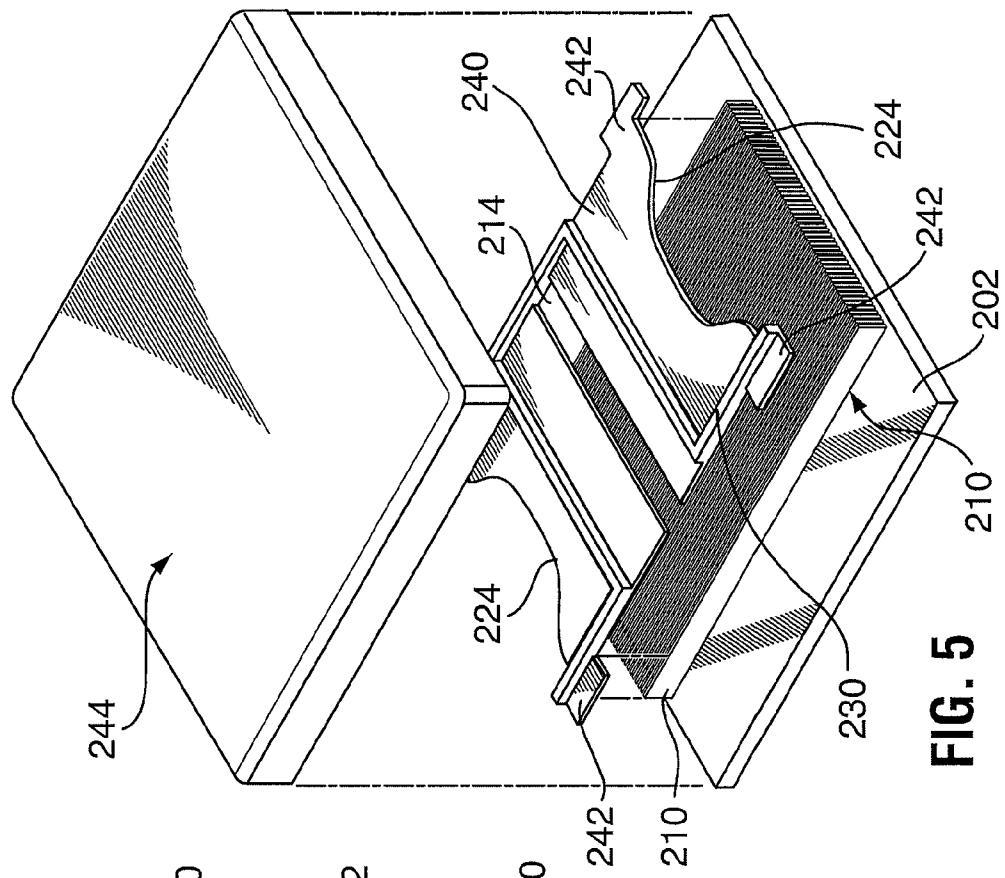


FIG. 5

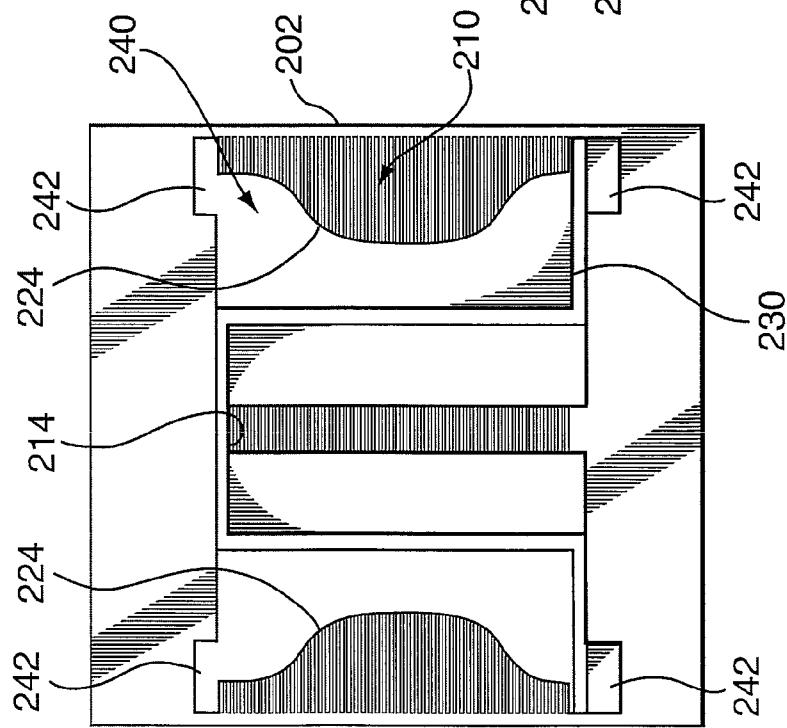


FIG. 4

US 8,746,330 B2

1**FLUID HEAT EXCHANGER CONFIGURED
TO PROVIDE A SPLIT FLOW****FIELD**

The present invention is directed to a fluid heat exchanger and, in particular, a fluid heat exchanger for an electronics application such as in a computer system.

BACKGROUND

Fluid heat exchangers are used to cool electronic devices by accepting and dissipating thermal energy therefrom.

Fluid heat exchangers seek to dissipate to a fluid passing therethrough, thermal energy communicated to them from a heat source.

SUMMARY

In accordance with a broad aspect of the invention, there is provided a fluid heat exchanger comprising: a heat spreader plate including an intended heat generating component contact region; a plurality of microchannels for directing heat transfer fluid over the heat spreader plate, the plurality of microchannels each having a first end and an opposite end and each of the plurality of microchannels extending substantially parallel with each other microchannel and each of the plurality of microchannels having a continuous channel flow path between their first end and their opposite end; a fluid inlet opening for the plurality of microchannels and positioned between the microchannel first and opposite ends, a first fluid outlet opening from the plurality of microchannels at each of the microchannel first ends; and an opposite fluid outlet opening from the plurality of microchannels at each of the microchannel opposite ends, the fluid inlet opening and the first and opposite fluid outlet openings providing that any flow of heat transfer fluid that passes into the plurality of microchannels, flows along the full length of each of the plurality of microchannels in two directions outwardly from the fluid inlet opening.

In accordance with another broad aspect of the present invention, there is provided a method for cooling a heat generating component comprising: providing a fluid heat exchanger including a heat spreader plate; a plurality of microchannels for directing heat transfer fluid over the heat spreader plate, the plurality of microchannels each having a first end and an opposite end and each of the plurality of microchannels having a continuous channel flow path between their first ends and their opposite ends; a fluid inlet opening for the plurality of microchannels and positioned between the microchannel first and opposite ends, a first fluid outlet opening from the plurality of microchannels at each of the microchannel first ends; and an opposite fluid outlet opening from the plurality of microchannels at each of the microchannel opposite ends; mounting the heat spreader plate onto the heat generating component creating a heat generating component contact region where the heat generating component contacts the heat spreader plate; introducing a flow of heat exchanging fluid to the fluid heat exchanger; urging the flow of heat exchanging fluid through the fluid inlet into the plurality of microchannels first to a microchannel region between the ends of the microchannel; and, diverting the flow of heat exchanging fluid into a plurality of subflows that each flow away from the other, a first of the plurality of subflows flowing from the fluid inlet toward the first fluid outlet and a second of the plurality of subflows flowing from the fluid inlet toward the opposite fluid outlet.

2

It is to be understood that other aspects of the present invention will become readily apparent to those skilled in the art from the following detailed description, wherein various embodiments of the invention are shown and described by way of illustration. As will be realized, the invention is capable for other and different embodiments and its several details are capable of modification in various other respects, all without departing from the spirit and scope of the present invention.

Accordingly the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the drawings wherein like reference numerals indicate similar parts throughout the several views, several aspects of the present invention are illustrated by way of example, and not by way of limitation, in detail in the figures, wherein:

FIG. 1 is a top plan view of a fluid heat exchanger according to one embodiment of the invention, with the top cap cut away to facilitate viewing internal components;

FIG. 2 is a sectional view along line II-II of FIG. 1;

FIG. 3 is a sectional view along line III-III of FIG. 1;

FIG. 4 is an exploded, perspective view of a fluid heat exchanger according to another embodiment of the invention; and

FIG. 5 is a top plan view of the fluid heat exchanger of FIG. 4 assembled with its top cap removed.

DESCRIPTION OF VARIOUS EMBODIMENTS

The detailed description set forth below in connection with the appended drawings is intended as a description of various embodiments of the present invention and is not intended to represent the only embodiments contemplated by the inventor. The detailed description includes specific details for the purpose of providing a comprehensive understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced without these specific details.

With reference to FIGS. 1 to 3, a fluid heat exchanger 100 is shown. Fluid heat exchanger 100 includes a heat spreader plate 102, an arrangement of fluid microchannels 103 defined between walls 110, a fluid inlet passage 104, and a fluid outlet passage 106. A housing 109 operates with heat spreader plate 102 to form an outer limit of the heat sink and to define fluid flow passages 104, 106.

As shown in FIGS. 2 and 3, in use the heat exchanger 100 is coupled to a heat source 107, such as an electronic device, including, but not limited to a microchip or an integrated circuit. The heat exchanger may be thermally coupled to the heat source by a thermal interface material disposed therebetween, by coupling directly to the surface of the heat source, or by integrally forming the heat source and at least the heat spreader plate 102 of the fluid heat exchanger. The heat exchanger 100 may take various forms and shapes, but heat spreader plate 102 is formed to accept thermal energy from heat source 107. Heat spreader plate 102 includes an intended heat generating component contact region 102b positioned in a known location thereon. In the illustrated embodiment, heat spreader plate 102 includes a protrusion at region 102b that controls the positioning of the heat spreader plate relative to the heat source, but such a protrusion need not be included. Heat spreader plate 102 may include a portion of more conductive material to facilitate and control heat transfer, if desired. In any event, heat spreader plate is formed to fit over

US 8,746,330 B2

3

and thermally communicate with a heat source in a region **102b**, usually located centrally relative to the edges of the heat spreader plate.

Microchannels **103** are formed to accept and allow passage therethrough of the flow of heat exchanging fluid such that the fluid can move along heat spreader plate **102** and walls **110** and accept and dissipate heat energy from them. In the illustrated embodiment, microchannels **103** are defined by walls **110** that are thermally coupled to the heat spreader plate to accept thermal energy therefrom. For example, heat spreader plate **102** may include an inner facing, upper surface **102a** and a plurality of microchannel walls **110** may extend upwardly therefrom, whereby the channel area, defined between upper surface **102a** and the microchannel walls **110**, channels or directs fluid to create a fluid flow path. The channel area may be open or filled with thermally conductive porous material such as metal or silicon foam, sintered metal, etc. Thermally conductive, porous materials allow flow through the channels but create a tortuous flow path.

Surface **102a** and microchannel walls **110** allow the fluid to undergo exchange of thermal energy from the heat spreader plate to cool the heat source coupled to the heat spreader plate. The upper surface **102a** and walls **110** have a high thermal conductivity to allow heat transfer from the heat source **107** to fluid passing through channels **103**. The surfaces forming channels **103** may be smooth and solid, formed with a porous structure, such as of sintered metal and/or metal or silicon foam or roughened, for example, including troughs and/or crests designed to collect or repel fluid from a particular location or to create selected fluid flow properties. Facing microchannel walls **110** may be configured in a parallel configuration, as shown, or may be formed otherwise, provided fluid can flow between the microchannel walls **110** along a fluid path. It will be apparent to one skilled in the art that the microchannel walls **110** may be alternatively configured in any other appropriate configuration depending on various factors of desired flow, thermal exchange, etc. For instance, grooves may be formed between sections of microchannel walls **110**. Generally, microchannel walls **110** may desirably have dimensions and properties which seek to reduce or possibly minimize the pressure drop or differential of fluid flowing through the channels **103** defined therebetween.

The microchannel walls **110** may have a width dimension within the range of 20 microns to 1 millimeter and a height dimension within the range of 100 microns to five millimeters, depending on the power of the heat source **107**, desired cooling effect, etc. The microchannel walls **110** may have a length dimension which ranges between 100 microns and several centimeters, depending on the dimensions of, and the heat flux density from, the heat source. In one embodiment, the walls **110** extend the full length (which may be a width) dimension of the heat spreader plate passing fully through region **102b**. These are exemplary dimensions and, of course, other microchannel wall dimensions are possible. The microchannel walls **110** may be spaced apart by a separation dimension range of 20 microns to 1 millimeter, depending on the power of the heat source **107**, although other separation dimensions are contemplated.

Other microporous channel configurations may be used alternatively to, or together with, microchannels, such as for example, a series of pillars, fins, or undulations, etc. which extend upwards from the heat spreader plate upper surface or tortuous channels as formed by a foam or sintered surface.

Fluid heat exchanger **100** further includes a fluid inlet passage **104**, which in the illustrated embodiment includes a

4

port **111** through the housing opening to a header **112** and thereafter a fluid inlet opening **114** to the microporous fluid channels **103**.

The port and the header can be formed in various ways and configurations. For example, port **111** may be positioned on top, as shown, side or end regions of the heat exchanger, as desired. Port **111** and header **112** are generally of a larger cross sectional area than opening **114**, so that a mass flow of fluid can be communicated substantially without restriction to opening **114**.

Although only a single fluid inlet opening **114** is shown, there may be one or more fluid inlet openings providing communication from the header to the fluid microchannels **103**.

Fluid inlet opening **114** may open to microchannels **103** opposite the heat spreader plate such that fluid passing through the opening may pass between walls **110** toward surface **102a**, before being diverted along the axial length of the channels, which extend parallel to axis x. Since most installations will position the heat spreader plate as the lowermost, as determined by gravity, component of heat exchanger **100**, the fluid inlet openings **114** can generally be described as being positioned above the microchannels **103** such that fluid may flow through opening **114** down into the channels in a direction orthogonal relative to the plane of surface **102a** and towards surface **102a** and then change direction to pass along the lengths of channels **103** substantially parallel to surface **102a** and axis x. Such direction change is driven by impingement of fluid against surface **102a**.

Fluid inlet opening **114** may be positioned adjacent to the known intended heat generating component contact region **102b** since this region of the heat spreader plate may be exposed to greater inputs of thermal energy than other regions on plate **102**. Positioning the fluid inlet opening adjacent region **102b** seeks to introduce fresh heat exchanging fluid first and directly to the hottest region of the heat exchanger. The position, arrangement and/or dimensions of opening **114** may be determined with consideration of the position of region **102b** such that opening **114** may be placed adjacent, for example orthogonally opposite to, or according to the usual mounting configuration above, the intended heat generating component contact region **102b** on the heat plate. The delivery of fresh fluid first to the region that is in direct communication with the heat generating component to be cooled seeks to create a uniform temperature at the contact region as well as areas in the heat spreader plate away from the contact region.

In the illustrated embodiment, opening **114** is positioned to have its geometric center aligned over the center, for example the geometric center, of region **102b**. It is noted that it may facilitate construction and installation by intending, and possibly forming, the heat sink spreader plate to be installed with the heat generating component positioned on the plate substantially centrally, with respect to the plate's perimeter edges, and then opening **114** may be positioned also with its geometric center substantially centrally with respect to the perimeter edges of the heat spreader plate. In this way, the geometric center points of each of opening **114**, the heat spreader plate and the heat generating component may all be substantially aligned, as at C.

Opening **114** may extend over any channel **103** through which it is desired that heat exchange fluid flows. Openings **114** may take various forms including, for example, various shapes, various widths, straight or curved edges (in plane or in section) to provide fluid flow features, open area, etc., as desired.

US 8,746,330 B2

5

Heat exchanger 100 further includes a fluid outlet passage 106, which in the illustrated embodiment includes one or more fluid outlet openings 124 from the microporous fluid channels 103, a header 126 and an outlet port 128 opening from the housing. Although two fluid outlet openings 124 are shown, there may be one or more fluid outlet openings providing communication to the header from the fluid channels 103.

The port and the header can be formed in various ways and configurations. For example, port 128 may be positioned on top, as shown, side or end regions of the heat exchanger, as desired.

Fluid outlet openings 124 may be positioned at the end of microchannels 103. Alternately or in addition, as shown, fluid outlet openings 124 may create an opening opposite heat spreader plate 102 such that fluid passing through the channels pass axially along the length of the channels between walls 110 and then changes direction to pass away from surface 102a out from between the walls 110 to exit through openings 124. Since most installations will position the heat spreader plate as the lowermost, as determined by gravity, component of heat exchanger 100, the fluid outlet openings 124 will generally be positioned above the microchannels 103 such that fluid may flow from the channels upwardly through openings 124.

Fluid outlet openings 124 may be spaced from fluid inlet openings 114 so that fluid is forced to pass through at least a portion of the length of channels 103 where heat exchange occurs before exiting the microchannels. Generally, fluid outlet openings 124 may be spaced from the known intended heat generating component contact region 102b.

In the illustrated embodiment, where heat exchanger 100 is intended to be mounted with heat source 107 generally centrally positioned relative to the perimeter edges of heat spreader plate 102, and thereby the ends 103a of channels, openings 124 may be positioned at or adjacent channel ends 103a.

At least one opening 124 extends over any channel 103 through which it is desired that heat exchange fluid flows. Openings 124 may take various forms including, for example, various shapes, various widths, straight or curved edges (in plane or in section) to provide fluid flow features, open area, etc. as desired.

Fluid inlet opening 114 may open away from the ends of the microchannels, for example along a length of a microchannel between its ends. In this way, fluid is introduced to a middle region of a continuous channel 103 rather than fluid being introduced to one end of a channel and allowing it to flow the entire length of the channel. In the illustrated embodiment, heat exchanger 100 is intended to be mounted with heat source 107 generally centrally positioned relative to the perimeter edges of heat spreader plate 102. As such, in the illustrated embodiment, opening 114 is positioned generally centrally relative to the edges of the heat plate 102. Since the channels, in the illustrated embodiment extend substantially continuously along the length of the heat plate between opposing side perimeter edges thereof, opening 114 opens generally centrally between ends 103a of each channel. For example, opening 114 may be positioned in the middle 50% of the heat exchanger or possibly the middle 20% of the heat exchanger. The delivery of fresh fluid to the central region where the heat generating component is in direct communication with the heat spreader plate, first before passing through the remaining lengths of channels seeks to create a uniform temperature at region 102b as well as areas in the heat spreader plate adjacent to the intended mounting position. The introduction of fluid to a region along a middle

6

region of the microchannels after which the flow splits into two sub flows to pass outwardly from the inlet towards a pair of outlets, each of which is positioned at the ends of the channels reduces the pressure drop of fluid passing along the channels over that pressure drop that would be created if the fluid passed along the entire length of each channel. Splitting the fluid flow to allow only approximately one half of the mass inlet flow to pass along any particular region of the microchannels creates less back pressure and less flow resistance, allows faster fluid flow through the channels and lessens the pump force required to move the fluid through the heat exchanger.

In use, heat spreader plate 102 is positioned in thermal communication with heat source 107 at region 102b. Heat generated by heat source 107 is conducted up through heat spreader plate 102 to surface 102a and walls 110. Heat exchanging fluid, as shown by arrows F, enters the fluid heat exchanger through port 111, passes into the header 112 and through opening 114. The heat exchanging fluid then passes down between walls 110 into channels 103, where the fluid accepts thermal energy from the walls 110 and surface 102a. The heat exchanging fluid, after passing down into the channels, then impinges against surface 102a to be diverted toward ends 103a of the channels toward outlet openings 124. In so doing, in the illustrated embodiment, the fluid is generally split into two subflows moving away from each other and away from inlet 114 toward openings 124 at the ends of the microchannels. Fluid passing through channels becomes heated, especially when passing over the region in direct contact with the heat source, such as, in the illustrated embodiment, the central region of the heat spreader plate. Heated fluid passes out of openings 124, into header and thereafter through port 128. The heated fluid will circulate through a heat sink where its thermal energy is unloaded before circulating back to port 111.

The individual and relative positioning and sizing of openings 114 and 124 may allow fluid to circulate through the heat exchanging channels 103 while reducing the pressure drop generated in fluid passing through heat exchanger 100, when compared to other positionings and sizings. In the illustrated embodiment, for example, the central region 124a of outlet openings 124 are scalloped to offer an enlarged outlet region from the centrally located channels, relative to those on the edges. This shaping provides that the outlet openings from some centrally positioned channels 103, relative to the sides of the heat exchanger, are larger than the outlet openings from other channels closer to the edges. This provides that fluid flowing through the more centrally located channels encounters less resistance to flow therethrough, again facilitating flow past the central mounting region 102b on heat spreader plate 102.

A seal 130 separates fluid inlet passage 104 from fluid outlet passage 106 so that fluid must pass through the microporous channels 103 past heat spreader plate surface 102a.

With reference to FIGS. 4 and 5, a useful method for manufacturing a fluid heat exchanger is described. A heat spreader plate 202 may be provided which has heat conductive properties through its thickness at least about a central region thereof.

Microchannels may be formed on the surface of the heat spreader plate, as by adding walls or forming walls by building up or removing materials from the surface of the heat plate. In one embodiment, skiving is used to form walls 210.

A plate 240 may be installed over the walls 210 to close off the channels across the upper limits of walls 210. Plate 240 has portions removed to create inlet and outlet openings 214

US 8,746,330 B2

7

and 224, respectively, in the final heat exchanger. Tabs 242 may be used to assist with the positioning and installation of plate 240, wherein tabs 242 are bent down over the two outermost walls.

Seal 230 may be installed as a portion of plate 240 or 5 separately.

After plate 240 and seal 230 are positioned, a top cap 244 can be installed over the assembly. Top cap 244 can include side walls that extend down to a position adjacent heat spreader plate. The parts may be connected during assembly 10 thereof or afterward by overall fusing techniques. In so doing, the parts are connected so that short circuiting from inlet passage to outlet passage is substantially avoided, setting up the fluid circuit as described herein above wherein the fluid flows from opening 214 to openings 224 through the channels 15 defined between walls 210.

The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to those embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein, but is to be accorded the full scope consistent with the claims, wherein 20 reference to an element in the singular, such as by use of the article "a" or "an" is not intended to mean "one and only one" unless specifically so stated, but rather "one or more". All structural and functional equivalents to the elements of the various embodiments described throughout the disclosure 25 that are known or later come to be known to those of ordinary skill in the art are intended to be encompassed by the elements of the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 USC 112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or "step for".

I claim:

1. A fluid heat exchanger comprising:
a heat spreader plate defining an upper surface;
a plurality of fins extending from respective proximal ends positioned adjacent the upper surface of the heat spreader plate to respective distal ends positioned distally from the upper surface of the heat transfer plate, wherein the plurality of fins defines a corresponding plurality of microchannels configured to direct a heat transfer fluid over the heat spreader plate, wherein each microchannel in the plurality of microchannels has a first end and an opposite end, wherein each microchannel in the plurality of microchannels extends substantially parallel with each other microchannel in the plurality of microchannels and has a continuous channel flow path between its respective first end and its respective opposite end;
- a plate positioned over the distal ends of the plurality of fins and the corresponding plurality of microchannels to close off the plurality of microchannels adjacent the distal ends of the plurality of fins, wherein the plate positioned over the plurality of distal fin ends defines an elongate fluid inlet opening overlying and extending transversely relative to the plurality of microchannels between the plurality of microchannel first ends and opposite ends, wherein the plate is so positioned over the plurality of fins as to define a first fluid outlet opening from each microchannel in the plurality of microchannels at each of the microchannel first ends and an oppo-

8

site fluid outlet opening from each microchannel in the plurality of microchannels at each of the microchannel opposite ends;

a housing spaced from the plate positioned over the plurality of distal fin ends, wherein the housing defines an inlet and an outlet, wherein the inlet defined by the housing opens to an inlet header and at least the first fluid outlet opening from each microchannel in the plurality of microchannels opens to an outlet header, wherein the outlet defined by the housing opens from the outlet header; and

a seal extending between the housing and the plate positioned over the plurality of distal fin ends, wherein the elongate fluid inlet opening defined by the plate extends between a proximal end and a distal end, wherein a region of the inlet header is positioned adjacent a first side of the fins and a region of the outlet header is positioned adjacent the second side of the fins, and wherein the fins, the plate, the housing, and the seal are arranged such that the heat transfer fluid is directed from the inlet opening to the inlet header, through the elongate fluid inlet opening defined by the plate and into the microchannels, from the microchannels to the outlet header, and from the outlet header to the outlet defined by the housing.

2. A fluid heat exchanger according to claim 1 wherein the elongate fluid inlet opening is positioned in the middle 50% of a length measured between the microchannel first ends and the microchannel opposite ends.

3. A fluid heat exchanger according to claim 1 wherein the elongate fluid inlet opening is positioned in the middle 20% of a length measured between the microchannel first ends and the microchannel opposite ends.

4. A fluid heat exchanger according to claim 1 wherein the heat spreader plate has an intended heat generating component contact region in a known location on the heat spreader plate and wherein the fluid inlet opening is positioned adjacent a central region of the intended heat generating component contact region.

5. A fluid heat exchanger according to claim 1 wherein the heat spreader plate includes perimeter edges and a length measured therebetween from perimeter edge to perimeter edge, and wherein the plurality of microchannels extends substantially the length of the heat spreader plate.

6. A fluid heat exchanger according to claim 1 wherein the elongate fluid inlet opening defined by the plate is positioned opposite the heat spreader plate such that fluid passing through the fluid inlet opening defined by the plate into the plurality of microchannels moves orthogonally relative to and toward a plane defined by the upper surface of the heat spreader plate.

7. A fluid heat exchanger according to claim 1 wherein the first fluid outlet opening is positioned opposite the heat spreader plate such that fluid passing from the plurality of microchannels through the first fluid outlet opening moves orthogonally relative to and away from a plane defined by the upper surface of the heat spreader plate.

8. A fluid heat exchanger according to claim 1 wherein the elongate fluid inlet opening opens into each of the plurality of microchannels defined by the plurality of fins extending from the heat spreader plate.

9. A fluid heat exchanger according to claim 1 wherein the plurality of microchannels includes a first microchannel and a second microchannel spaced from the first microchannel; 65 wherein the first fluid outlet opening from the first microchannel is larger than either of the first outlet opening and the opposite outlet opening of the second microchannel such that

US 8,746,330 B2

9

less flow resistance occurs through the first microchannel to allow greater flow therethrough during steady-state operation of the fluid heat exchanger.

10. A fluid heat exchanger according to claim 1 wherein the plate positioned over the distal ends of the plurality of fins defines a scalloped edge overlying the plurality of microchannels adjacent the microchannel first ends and thereby defines a relatively larger outlet opening from a relatively more centrally located microchannel as compared to an outlet opening from relatively less centrally located microchannels.

11. A fluid heat exchanger according to claim 10, wherein the scalloped edge is configured to provide a relatively lower fluid resistance through a portion of the relatively more centrally located microchannel as compared to a fluid resistance through the relatively less centrally located microchannel.

12. A fluid heat exchanger comprising:

a plurality of juxtaposed fins defining a corresponding plurality of juxtaposed microchannels, wherein each microchannel extends between a first end and a second end;

a plate positioned over the juxtaposed fins and the corresponding plurality of juxtaposed microchannels, wherein the plate defines an elongate aperture extending transversely relative to each of the plurality of juxtaposed microchannels, wherein the elongate aperture is positioned between the first ends and the second ends of the plurality of juxtaposed microchannels;

a housing spaced apart from the plate, wherein the housing has an inlet aperture and an outlet aperture, wherein the inlet aperture opens to an inlet header region positioned adjacent a first side of the plurality of juxtaposed fins and the outlet aperture opens from an outlet header region positioned adjacent a second side of the plurality of juxtaposed fins opposite the first side of the plurality of fins, and wherein the elongate aperture of the plate extends away from the inlet header region transversely relative to the plurality of juxtaposed fins; and

a seal extending between the plate and the housing such that a flow of fluid from the inlet aperture of the housing to the inlet header region must pass through the elongate aperture of the plate and into the plurality of juxtaposed microchannels before the flow of the fluid passes through the outlet header region and the outlet aperture of the housing.

13. A fluid heat exchanger according to claim 12, wherein the plate comprises a scalloped edge to define a scalloped outlet from the plurality of juxtaposed microchannels.

14. A fluid heat exchanger comprising:

a plurality of juxtaposed fins defining a corresponding plurality of juxtaposed microchannels, wherein each microchannel extends between a respective first end and a respective second end;

an apertured plate overlying the microchannels and defining an inlet to the microchannels and an outlet from the microchannels;

a housing having an inlet and an outlet, wherein the inlet opens to an inlet header region juxtaposed with a first side of the plurality of juxtaposed fins, and wherein the outlet opens from an outlet header region juxtaposed with a second side of the plurality of juxtaposed fins, wherein the first side and the second side are positioned opposite relative to each other and wherein the inlet to the microchannels defined by the apertured plate

10

extends between the first side and the second side at a position between the first ends and the second ends; and a seal extending between the housing and the apertured plate, wherein the inlet to the microchannels is separated from the outlet from the microchannels by the seal such that a fluid flow from the inlet header region is directed through the inlet to the microchannels and into one or more of the microchannels before the fluid passes from the microchannels into the outlet header region and through the housing outlet.

15. A fluid heat exchanger according to claim 14, wherein the inlet header region juxtaposed with a first side of the plurality of juxtaposed fins constitutes a first portion of an inlet header, wherein a second portion of the inlet header extends transversely over the microchannels.

16. A fluid heat exchanger according to claim 14, wherein the apertured plate defines opposed first and second contoured edges positioned adjacent the first ends and the second ends of the microchannels, respectively, wherein the first contoured edge or the second contoured edge defines the relatively larger outlet opening from the relatively more centrally positioned microchannel.

17. A fluid heat exchanger according to claim 16, wherein the first and second contoured edges comprise respective first and second scalloped edges.

18. A fluid heat exchanger according to claim 15, wherein the inlet header is configured to distribute a flow of the fluid among the plurality of microchannels.

19. A fluid heat exchanger according to claim 15, wherein the inlet header is configured such that a flow of the fluid passes from the header through the inlet defined by the apertured plate.

20. A fluid heat exchanger according to claim 15, wherein the seal defines a boundary of the inlet header.

21. A fluid heat exchanger according to claim 1, wherein the inlet header is configured to distribute a flow of the heat transfer fluid among the plurality of microchannels.

22. A fluid heat exchanger according to claim 12, wherein the inlet header region defines a region of an inlet header, and the inlet header partially extends over the elongate inlet aperture defined by the plate, wherein the inlet header is configured to distribute the flow of fluid among the plurality of microchannels.

23. A fluid heat exchanger according to claim 22, wherein the inlet header region at least partially extends over the elongate inlet aperture.

24. A fluid heat exchanger according to claim 1, wherein at least a portion of the inlet header region extends over the elongate fluid inlet opening.

25. A fluid heat exchanger according to claim 15, wherein at least a portion of the inlet header region extends over the elongate fluid inlet opening.

26. A fluid heat exchanger according to claim 1, wherein the inlet header region has a relatively larger cross-sectional area than the housing inlet.

27. A fluid heat exchanger according to claim 12, wherein the inlet header region has a relatively larger cross-sectional area than the housing inlet.

28. A fluid heat exchanger according to claim 14, wherein the inlet header region has a relatively larger cross-sectional area than the housing inlet.

* * * * *